US009127681B2

(12) **United States Patent**
Ohtsuka et al.

(10) **Patent No.: US 9,127,681 B2**
(45) **Date of Patent: *Sep. 8, 2015**

(54) **CROSS-FLOW FAN, MOLDING DIE, AND FLUID FEEDER**

(75) Inventors: **Masaki Ohtsuka**, Osaka (JP); **Yukishige Shiraichi**, Osaka (JP)

(73) Assignee: **SHARP KABUSHIKI KAISHA**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 744 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/394,773**

(22) PCT Filed: **Sep. 7, 2010**

(86) PCT No.: **PCT/JP2010/065304**

§ 371 (c)(1), (2), (4) Date: **Mar. 7, 2012**

(87) PCT Pub. No.: **WO2011/030751**

PCT Pub. Date: **Mar. 17, 2011**

(65) **Prior Publication Data**

US 2012/0171013 A1 Jul. 5, 2012

(30) **Foreign Application Priority Data**

Sep. 9, 2009 (JP) 2009-208360

(51) **Int. Cl.**
F04D 29/66 (2006.01)
F04D 17/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F04D 17/04*** (2013.01); ***F04D 29/283*** (2013.01); ***F04D 29/30*** (2013.01); ***F04D 29/667*** (2013.01); *B29L 2031/087* (2013.01)

(58) **Field of Classification Search**
USPC .... 416/223 R, 228, 242, 243, 223 B; 415/206, 53.1, 53.2, 59.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,769,876 B2 * 8/2004 Sakai et al. 416/187
8,128,359 B2 3/2012 Chen
(Continued)

FOREIGN PATENT DOCUMENTS

CN 1840313 A 10/2006
JP 58-64895 U 5/1983
(Continued)

OTHER PUBLICATIONS

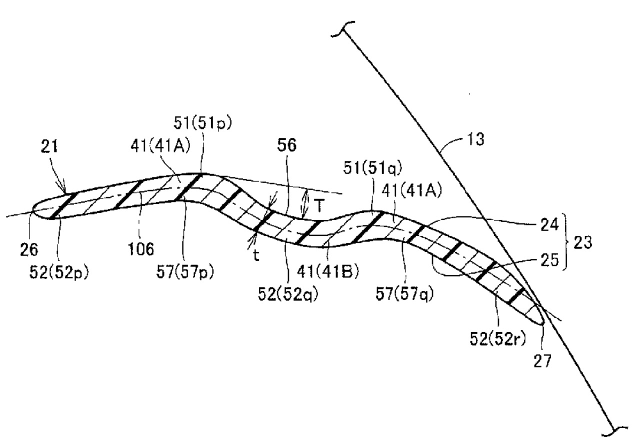
Chinese Office Action for corresponding Chinese Application No. 201080040054.0 mailed Mar. 27, 2014 with an English translation.
(Continued)

Primary Examiner — Dwayne J White
Assistant Examiner — Justin Seabe
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

A cross-flow fan includes a plurality of fan blades circumferentially spaced from each other. The fan blade has an inner edge portion on the radially inner side, and an outer edge portion on the radially outer side. A blade surface extends between the inner edge portion and the outer edge portion. The blade surface includes a pressure surface on the rotation direction side of the fan and a suction surface on the opposite side. In cross-section orthogonal to the rotation axis of the fan, the fan blade has a concave portions formed at the pressure surface and the suction surface. A plurality of concave portions are formed at pressure surface. Side fan provides excellent blowing capacity. Also disclosed are a molding die for use in production of the cross-flow fan, and a fluid feeder provided with the cross-flow fan.

12 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

F04D 29/28	(2006.01)
F04D 29/30	(2006.01)
B29L 31/08	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0177304 A1	8/2006	Omori et al.		
2009/0028719 A1 *	1/2009	Teraoka et al.	....	416/223 R
2010/0186357 A1	7/2010	Takeda et al.		

FOREIGN PATENT DOCUMENTS

JP	59-62293	U	4/1984
JP	63-31295	U	2/1988
JP	3-143620	A	6/1991
JP	5-106591	A	4/1993
JP	7-4388	A	1/1995
JP	8-247093	A	9/1996
JP	9-280196	A	10/1997
JP	2005-16315	A	1/2005
JP	2007-10259	A	1/2007
JP	2007-21352	A	2/2007
JP	2009-28681	A	2/2009

OTHER PUBLICATIONS

International Search Report (Form PCT/ISA/210), dated Dec. 21, 2010, for International Application No. PCT/JP2010/065303.

International Search Report (Form PCT/ISA/210), dated Dec. 21, 2010, for International Application No. PCT/JP2010/065304, with an English translation.

U.S. Office Action, dated Dec. 19, 2014, for U.S. Appl. No. 13/395,017.

Final Office Action for Co-Pending U.S. Appl. No. 13/395,017 mailed Apr. 23, 2015.

* cited by examiner

FIG.1

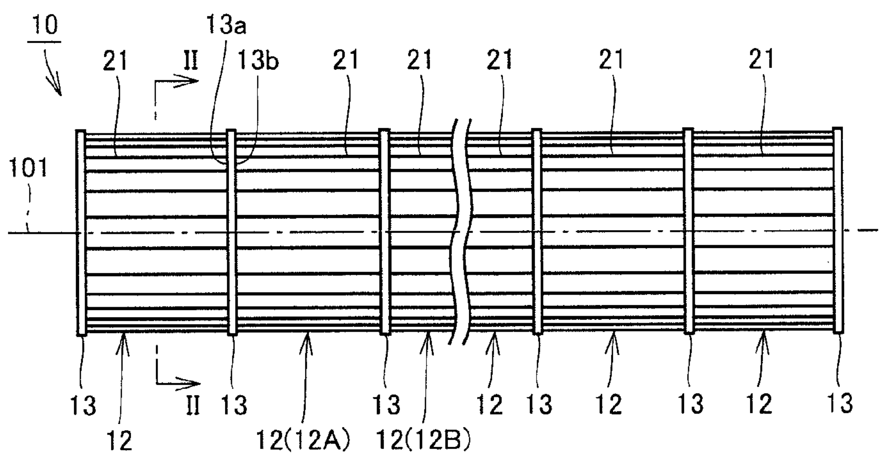

10
21
II
13a
13b
21
21
21
21
21
101
13
12
II
13
12(12A)
13
12(12B)
12
13
12
13
12
13

FIG.2

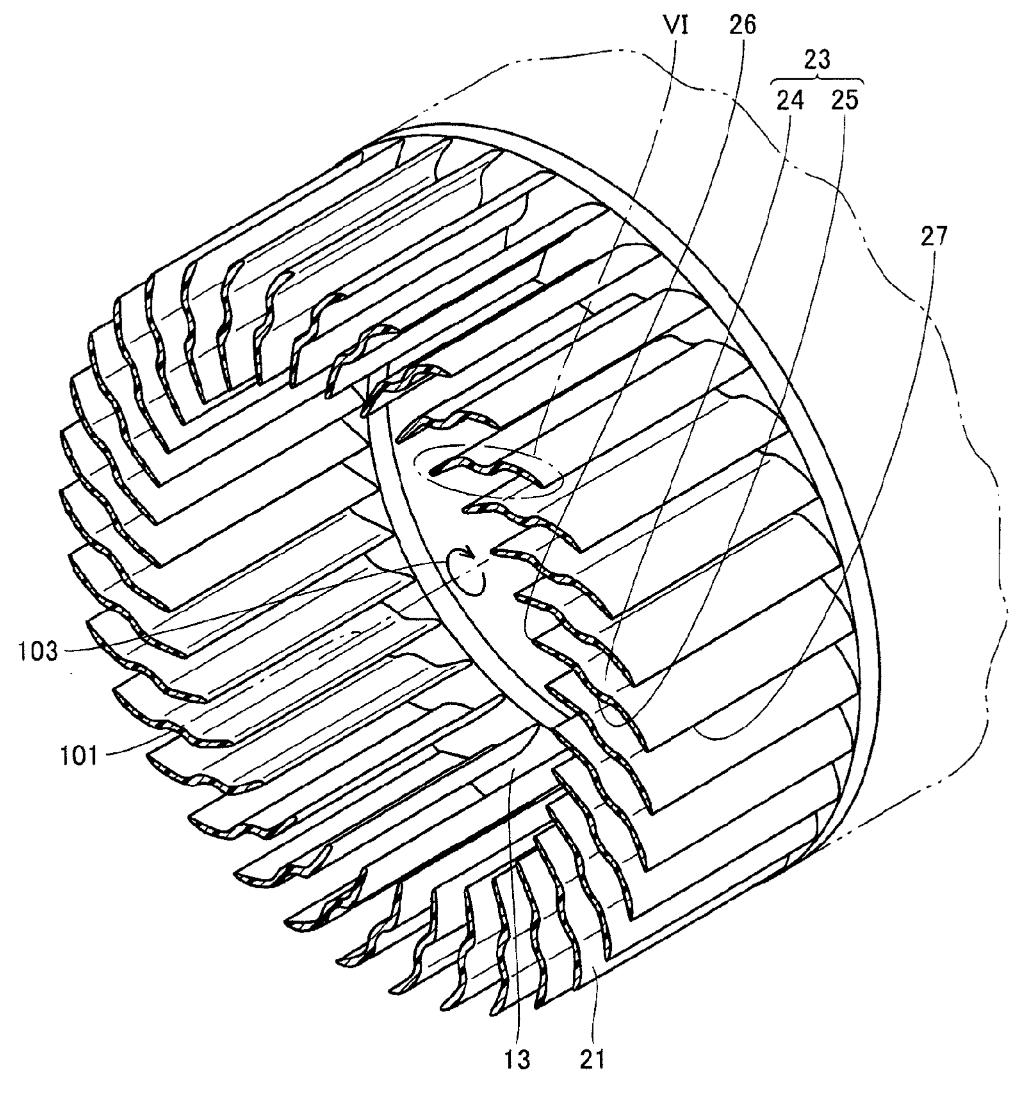
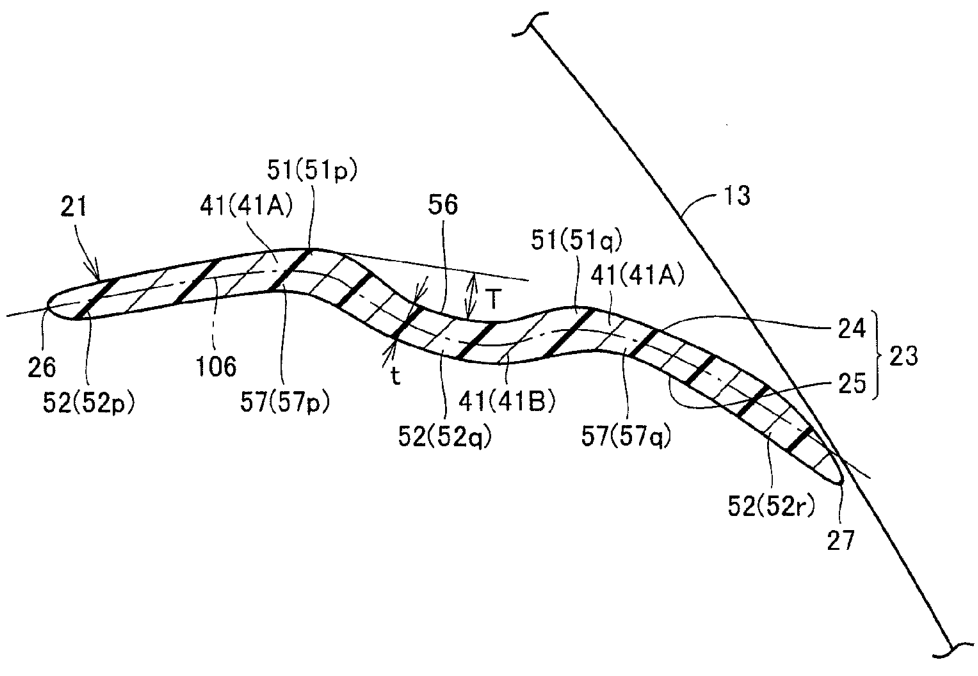


FIG.3


21
41(41A)
51(51p)
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T
51(51q)
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13
24
23
25
26
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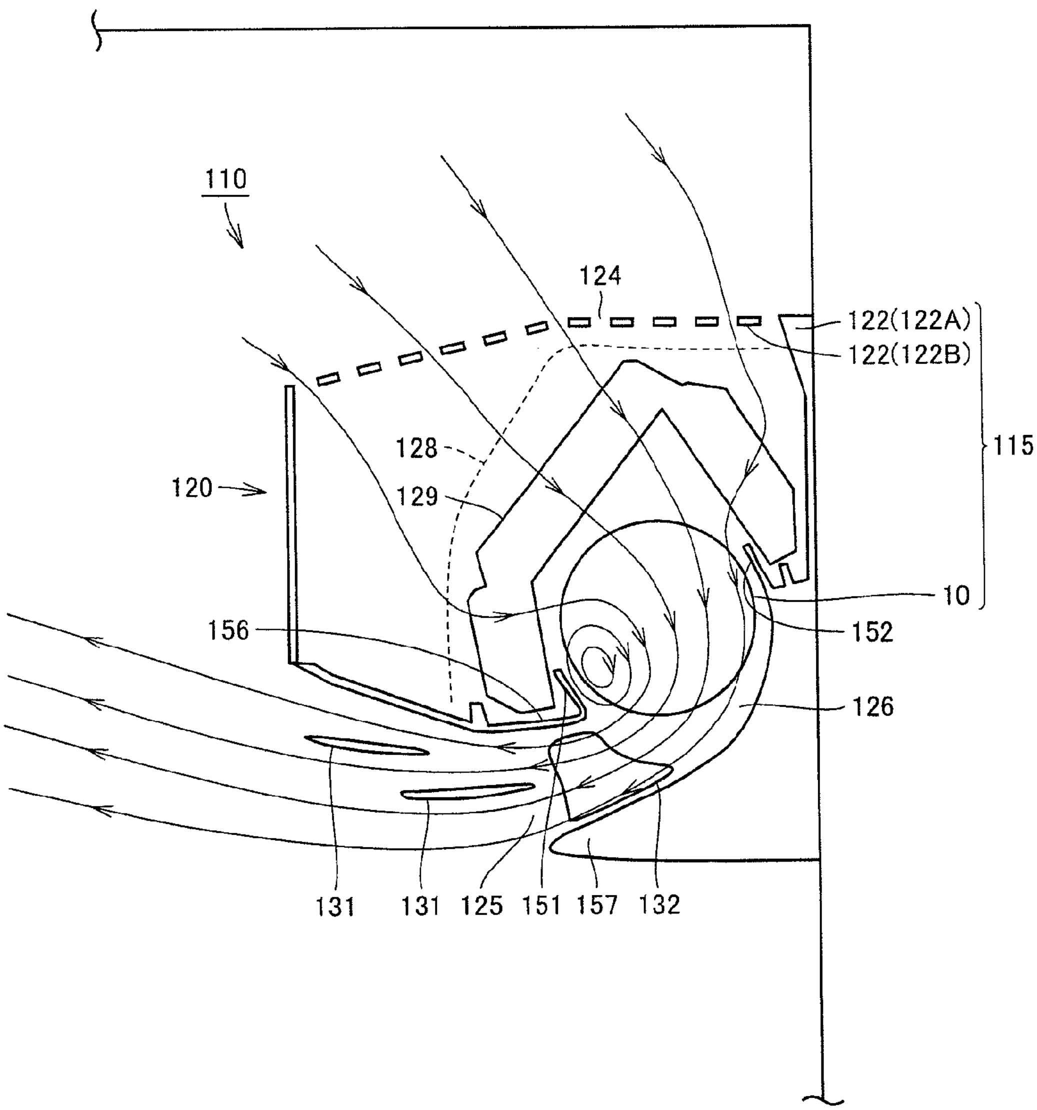
106
57(57p)
t
52(52q)
41(41B)
57(57q)
52(52r)
27

FIG.4


110
124
122(122A)
122(122B)
115
128
129
120
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152
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132

FIG.5

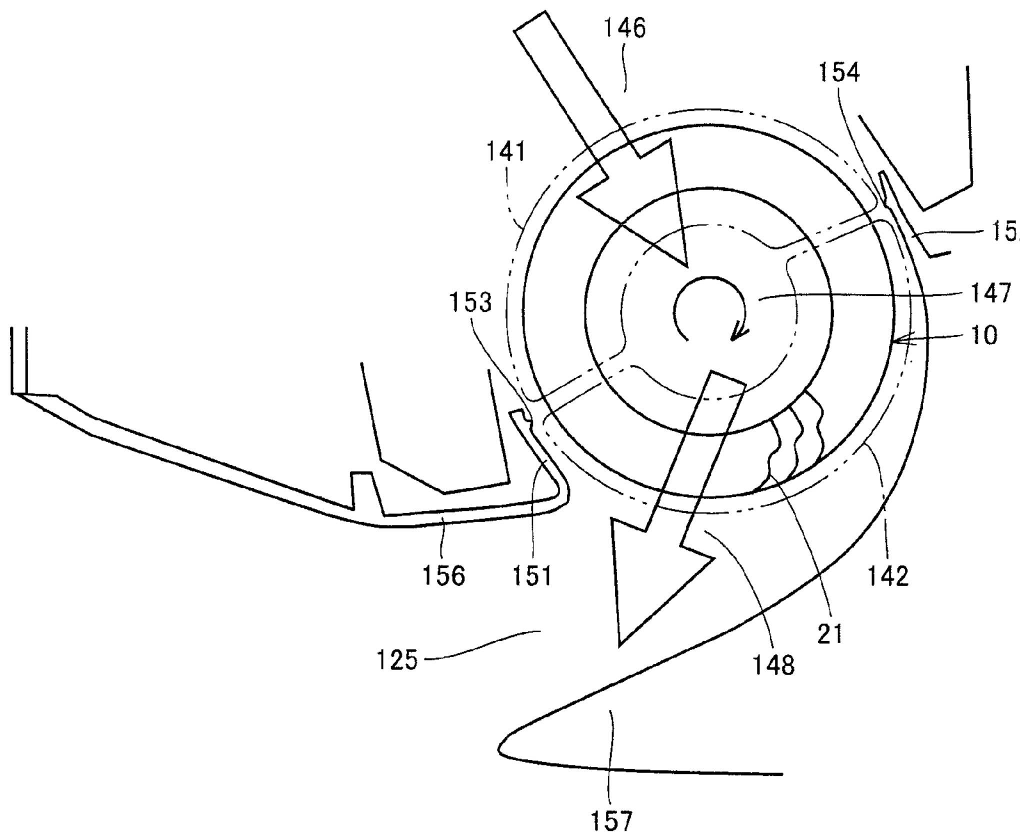


FIG.6

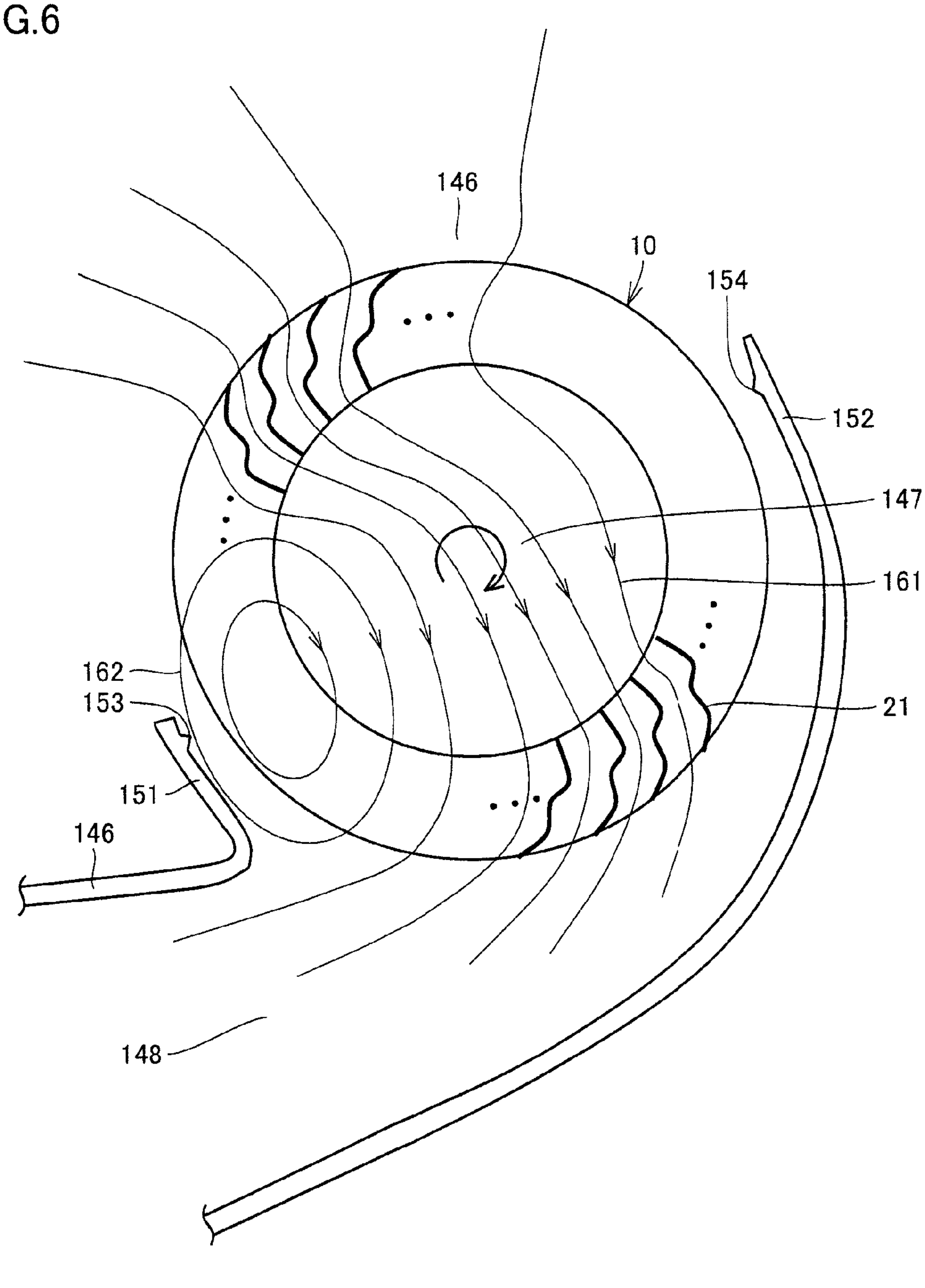
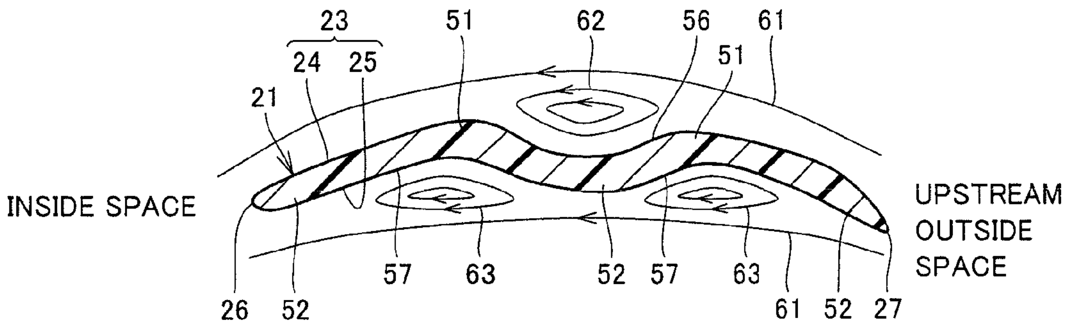


FIG.7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24
25
21
51
62
56
61
51
INSIDE SPACE
UPSTREAM
OUTSIDE
SPACE
26
52
57
63
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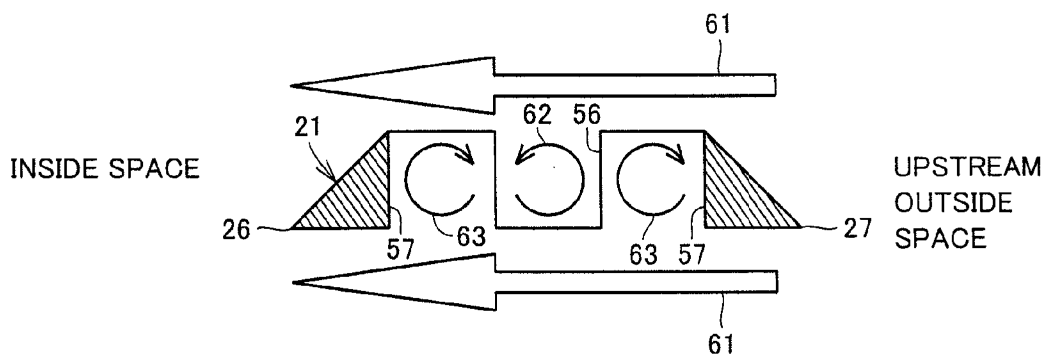
63
61
52
27

FIG.8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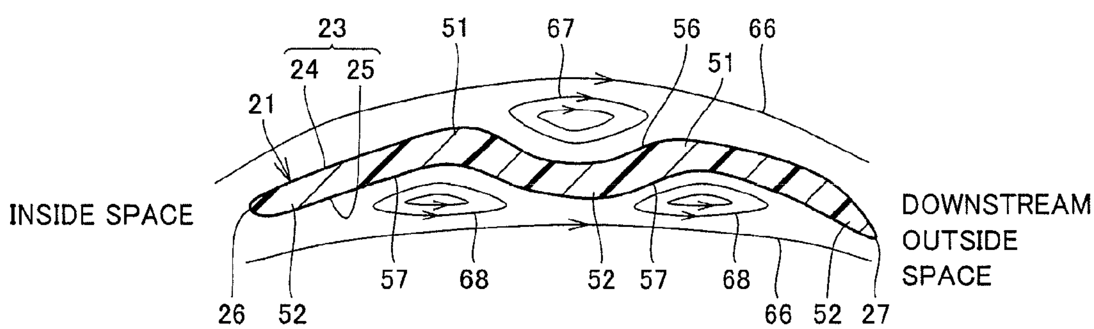
57
27
61

FIG.9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66
52
27

FIG.10

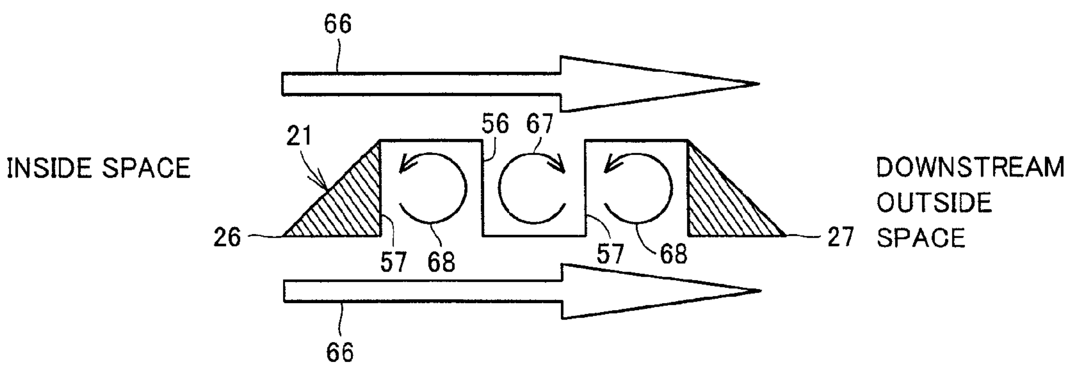
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FIG.11

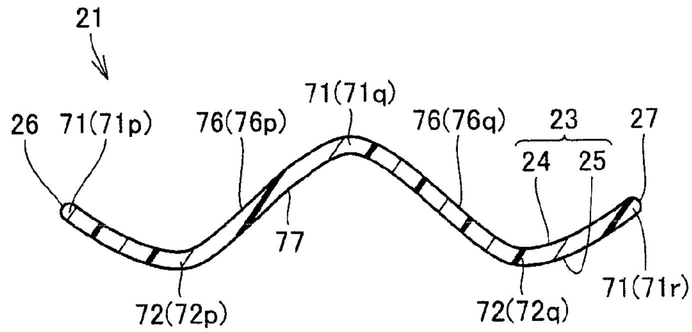


FIG.12

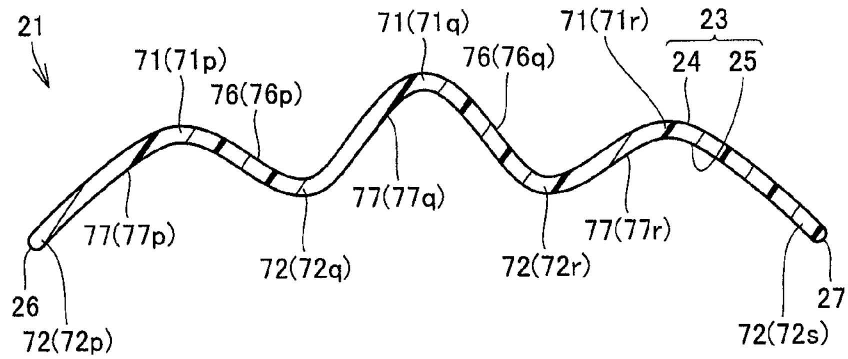


FIG.13

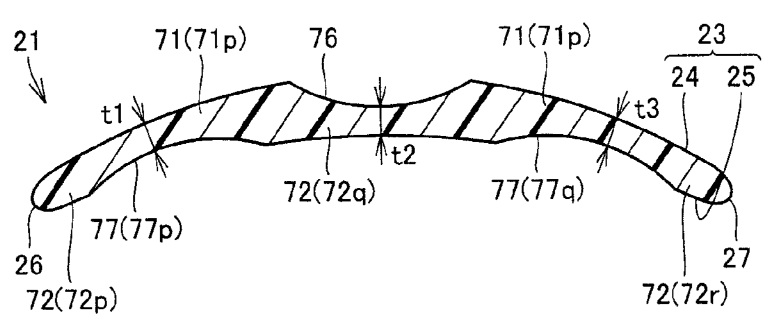


FIG.14

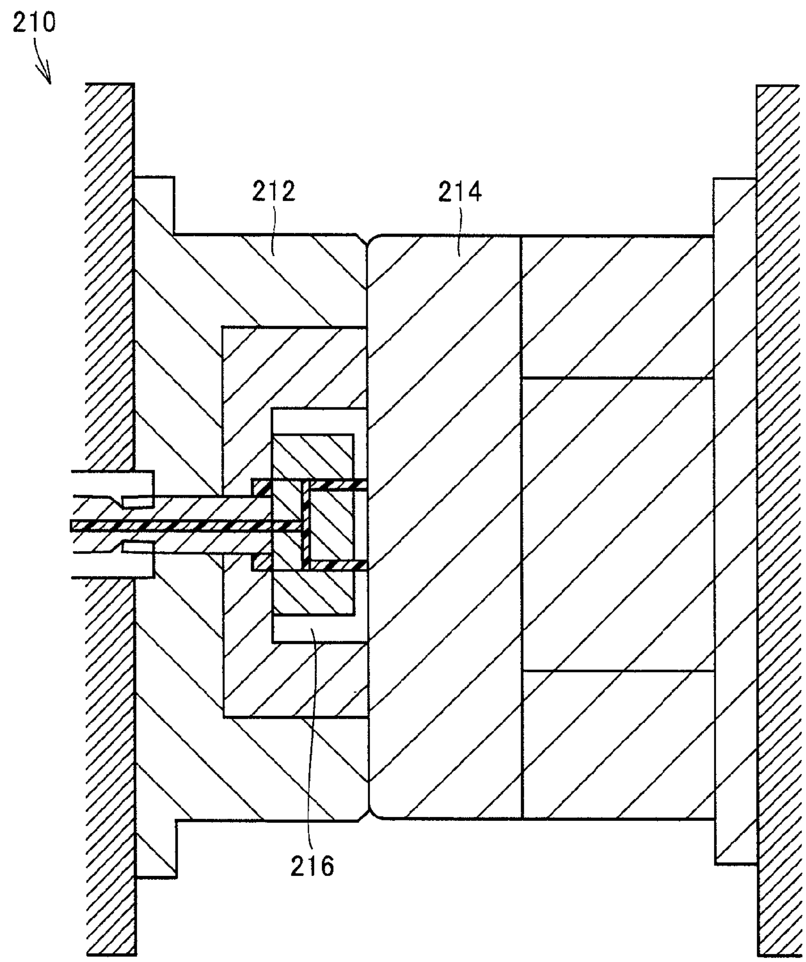
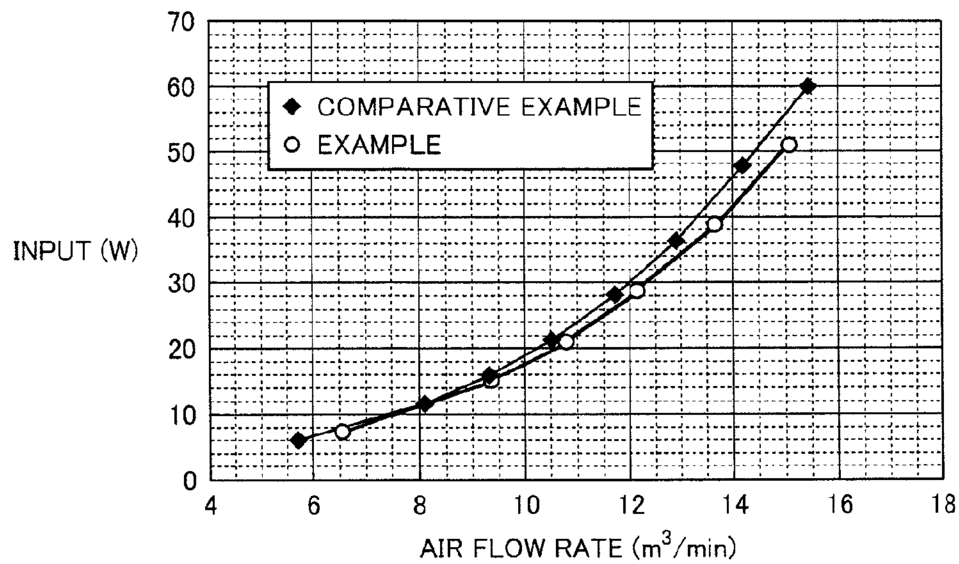


FIG.15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60
50
40
30
20
10
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INPUT (W)
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EXAMPLE
4
6
8
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12
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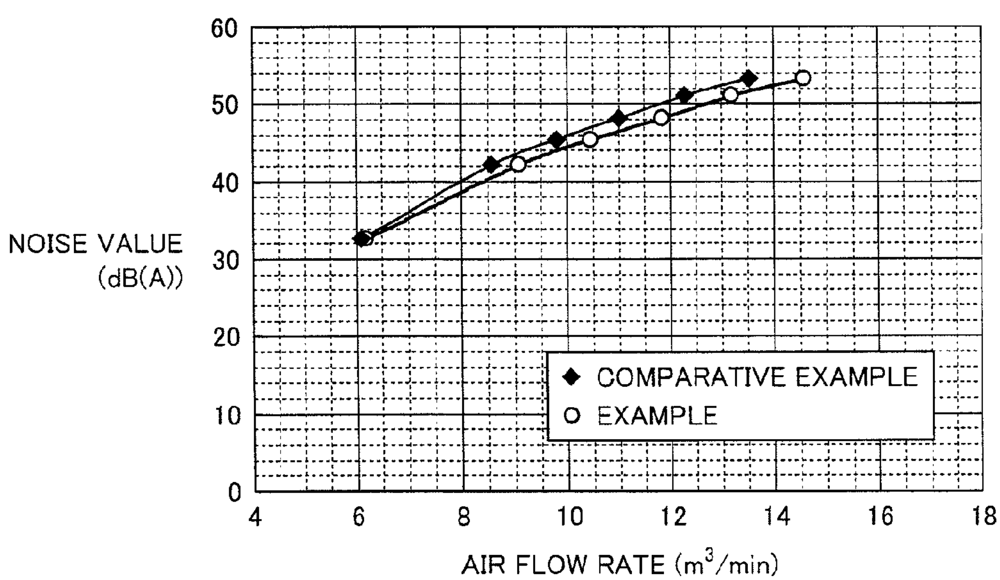
16
18
AIR FLOW RATE (m3/min)

FIG.16


60
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NOISE VALUE
(dB(A))
COMPARATIVE EXAMPLE
EXAMPLE
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12
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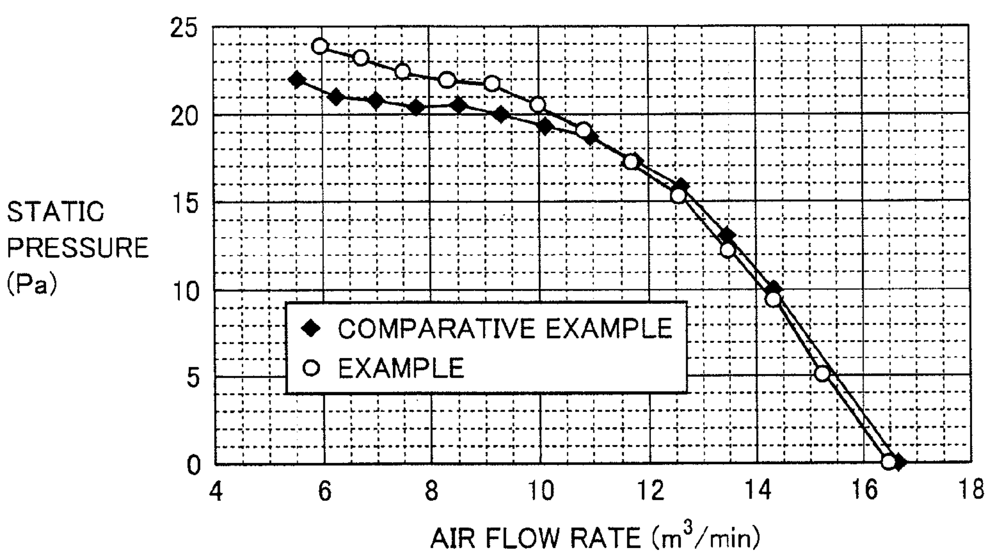
AIR FLOW RATE (m3/min)

FIG.17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STATIC
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(Pa)
COMPARATIVE EXAMPLE
EXAMPLE
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14
16
18
AIR FLOW RATE (m3/min)

CROSS-FLOW FAN, MOLDING DIE, AND FLUID FEEDER

TECHNICAL FIELD

The present invention relates to a cross-flow fan, a molding die, and a fluid feeder, and particularly to a cross-flow fan for an air conditioner and an air purifier, a molding die for use in production of the cross-flow fan, and a fluid feeder provided with the cross-flow fan.

BACKGROUND ART

As for conventional cross-flow fans, for example, Japanese Patent Laying-Open No. 2007-21352 discloses an air purifier which aims to reduce the installation area while increasing the blowing capacity (PTL 1). In the air purifier disclosed in PTL 1, a vertically long cross-flow fan driven by a motor is arranged in a body having an intake and an outlet at left and right ends, respectively.

CITATION LIST

Patent Literature

PTL 1: Japanese Patent Laying-Open No. 2007-21352

SUMMARY OF INVENTION

Technical Problem

In recent years, for conservation of global environment, further energy savings in home electric equipment are desired. For example, it is known that the efficiency of electric equipment such as an air conditioner and an air purifier greatly depends on the efficiency of a blower included therein. It is also known that reducing the weight of a fan blade provided as a rotating body in a blower reduces power consumption of a motor for rotatably driving the fan blade and improves the efficiency of the blower or a fluid feeder.

However, an aerofoil employed as the shape in cross section of a fan blade is essentially assumed to be applied to the wing of an air plane and is mainly found in the field of aeronautical engineering. Therefore, an aerofoil fan blade is mainly optimized in a high Reynolds number region and is not always appropriate as the cross section of a fan blade used in a low Reynolds number region for an air conditioner, an air purifier, etc. for home use.

When an aerofoil or double arc is employed as the cross-sectional shape of a fan blade, a thick portion exists in a range of 30 to 50% from the front edge of the fan blade. This increases the weight of the fan blade, which becomes a cause of increased friction loss during rotation. However, simply reducing the weight of a fan blade may reduce the strength of the fan blade and result in fracture or other poor quality.

For the reasons above, in order to save energy in electric equipment such as an air conditioner and an air purifier for home use, an appropriate blade cross-sectional shape has been sought for a fan blade to be used in the low Reynolds number region. A blade cross-sectional shape with a high lift-drag ratio, a small thickness and weight, and a high strength has also been sought.

Fans for use in an air blower include a cross-flow fan that forms an outlet flow in the form of a flat plane parallel to the rotation axis of the fan. Examples of typical application of the cross-flow fan include an air conditioner. Reducing power consumption of an air conditioner is a high priority when

more energy savings in home electric equipment are desired. There is a demand to increase air flow rate for the purpose of reducing power consumption of the air conditioner. The increase of air flow rate can increase the performance of evaporation and condensation of a heat exchanger and can reduce power consumption of a compressor, accordingly. However, the increase of air flow rate increases power consumption of the fan. Therefore, the balance between the reduction of power consumption in the compressor and the increase of power consumption in the fan amounts to a reduction of power consumption. Thus, the effect achieved by increasing the air flow rate of the fan cannot be maximized. On the other hand, if the rotation speed is increased with the same fan, as a means for increasing the air flow rate of the fan, the noise of the air conditioner is increased.

Another example of application of the cross-flow fan is an air purifier. An air purifier is requested to increase its dust-collecting capacity, that is, to increase the air flow rate, and to reduce noise. However, there is a tradeoff between these two requests.

In order to satisfy these two, it is necessary not only to reduce noise from the intake and the outlet of the air purifier but also to fundamentally reduce noise of the cross-flow fan that blows air. In order to increase the air flow rate, it is necessary to increase the rotation speed of the cross-flow fan. When the rotation speed of the cross-flow fan is increased, it is necessary to reduce input to the fan. It is also necessary to increase the strength of the fan blade to such an extent as to overcome the increased centrifugal force caused by the increased rotation speed of the cross-flow fan.

An object of the present invention is therefore to solve the aforementioned problems and to provide a cross-flow fan exhibiting an excellent blowing capacity, a molding die for use in production of the cross-flow fan, and a fluid feeder provided with the cross-flow fan.

Solution to Problem

A cross-flow fan according to the present invention includes a plurality of vane portions provided to be circumferentially spaced apart from each other. The vane portion has an inner edge portion arranged on a radially inner side to/from which air flows in/out and an outer edge portion arranged on a radially outer side to/from which air flows in/out. The vane portion has a blade surface extending between the inner edge portion and the outer edge portion. The blade surface includes a pressure surface arranged on a rotation direction side of the cross-flow fan and a suction surface arranged on a back side of the pressure surface. The vane portion has such a blade cross-sectional shape that a concave portion is formed at the pressure surface and the suction surface when the vane portion is cut along a plane orthogonal to a rotation axis of the cross-flow fan. A plurality of concave portions are formed at at least one of the pressure surface and the suction surface.

In the cross-flow fan configured in this manner, during rotation of the cross-flow fan, an air flow that flows in from the outer edge portion, passes through the blade surface, and flows out from the inner edge portion and an air flow that flows in from the inner edge portion, passes through the blade surface, and flows out from the outer edge portion are alternately produced in each vane portion. Here, a vortex of air flow (secondary flow) is generated in the concave portion, so that the air flow (main flow) passing through the blade surface flows along the outside of the vortex produced in the concave portion. Accordingly, the vane portion exhibits a behavior like a thick blade as if a blade cross sectional shape is increased in thickness by the amount of formation of the vortex. As a result, the blowing capacity of the cross-flow fan can be improved.

Preferably, the vane portion has a flection portion formed by flexing a center line of the blade cross-sectional shape extending between the inner edge portion and the outer edge portion, at a plurality of points. The concave portion is formed by the flection portion. In the cross-flow fan configured in this manner, a vortex of air flow is generated in the concave portion formed by the flection portion, thereby improving the blowing capacity of the cross-flow fan.

Preferably, the flection portion is flexed such that a depth of the concave portion is larger than a thickness of the vane portion at at least one point. In the cross-flow fan configured in this manner, a vortex of air flow can be generated in the concave portion more reliably.

Preferably, the concave portion is formed in the proximity of the inner edge portion and the outer edge portion. In the cross-flow fan configured in this manner, the above-noted effect achieved by the concave portion is brought about in the proximity of the inner edge portion and the outer edge portion, thereby generating a high lift. In addition, the formation of the flection portion can improve the strength of the vane portion in the proximity of the inner edge portion.

Preferably, the concave portion is formed at a blade central portion between the inner edge portion and the outer edge portion. In the cross-flow fan configured in this manner, the above-noted effect achieved by the concave portion is brought about in the blade central portion, so that the vane portion exhibits a stable ability as a blade. In addition, the formation of the flection portion can improve the strength of the vane portion at the blade central portion.

Preferably, the concave portion is formed to extend from one end to the other end of the blade surface in a rotation axis direction of the cross-flow fan. In the cross-flow fan configured in this manner, a vortex of air flow is generated in the concave portion formed to extend from one end to the other end of the blade surface in the rotation axis direction of the cross-flow fan, thereby improving the blowing capacity of the cross-flow fan more effectively.

Preferably, the concave portion is formed at the pressure surface and the suction surface to repeatedly appear in a direction in which the inner edge portion is connected with the outer edge portion. In the cross-flow fan configured in this manner, a vortex of air flow is generated in the concave portion which repeatedly appears at the pressure surface and the suction surface, thereby improving the blowing capacity of the cross-flow fan more effectively.

Preferably, the concave portion formed at the pressure surface forms a convex portion at the suction surface, and the concave portion formed at the suction surface forms a convex portion at the pressure surface. In the cross-flow fan configured in this manner, a blade cross-sectional shape having a concave portion at the pressure surface and at the suction surface can be easily obtained.

Preferably, in the blade cross-sectional shape, the concave portion is formed between convex portions appearing at the blade surface. The concave portion and the convex portions are formed to be alternately aligned in a direction in which the inner edge portion is connected with the outer edge portion. In the cross-flow fan configured in this manner, a vortex of air flow is generated in the concave portion formed between the convex portions, thereby improving the blowing capacity more effectively.

Preferably, the vane portion has the blade cross-sectional shape having a generally constant thickness between the inner edge portion and the outer edge portion. In the cross-flow fan configured in this manner, even when a vane portion having a blade cross-sectional shape having a generally constant thickness is used, the blowing capacity can be improved.

Preferably, the blade cross-sectional shape is approximately W-shaped. In the cross-flow fan configured in this manner, a vortex of air flow is generated in the concave portion appearing in the blade cross-sectional shape, thereby improving the blowing capacity of the cross-flow fan.

Preferably, the cross-flow fan is formed from resin. In the cross-flow fan configured in this manner, a light and high-strength cross-flow fan made of resin can be obtained.

A molding die according to the present invention is used to mold the cross-flow fan as described above. With the molding die configured in this manner, a light and high-strength cross-flow fan made of resin can be manufactured.

A fluid feeder according to the present invention includes a blower configured to include any of the cross-flow fan as described above and a driving motor coupled to the cross-flow fan to rotate a plurality of vane portions. In the fluid feeder configured in this manner, power consumption of the driving motor can be reduced while the blowing capacity is kept high.

Advantageous Effects of Invention

As described above, the present invention provides a cross-flow fan exhibiting an excellent blowing capacity, a molding die for use in production of the cross-flow fan, and a fluid feeder provided with the cross-flow fan.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a side view of a cross-flow fan in a first embodiment of the present invention.

FIG. **2** is a cross-sectional perspective view of the cross-flow fan taken along a line II-II in FIG. **1**.

FIG. **3** is a cross-sectional view of a fan blade provided in the cross-flow fan in FIG. **1**.

FIG. **4** is a cross-sectional view of an air conditioner using the cross-flow fan shown in FIG. **1**.

FIG. **5** is an enlarged cross-sectional view showing the proximity of an outlet port of the air conditioner in FIG. **4**.

FIG. **6** is a cross-sectional view of an air flow produced in the proximity of the outlet port of the air conditioner in FIG. **4**.

FIG. **7** is a cross-sectional view representing a phenomenon that occurs on a blade surface of the fan blade in an upstream region shown in FIG. **5**.

FIG. **8** is a diagram schematically representing the fan blade shown in FIG. **7**.

FIG. **9** is a cross-sectional view representing a phenomenon that occurs on the blade surface of the fan blade in a downstream region shown in FIG. **5**.

FIG. **10** is a diagram schematically representing the fan blade shown in FIG. **9**.

FIG. **11** is a cross-sectional view of a first modification of the cross-flow fan in FIG. **1**.

FIG. **12** is a cross-sectional view of a second modification of the cross-flow fan in FIG. **1**.

FIG. **13** is a cross-sectional view of a third modification of the cross-flow fan in FIG. **1**.

FIG. **14** is a cross-sectional view of a molding die for use in production of the cross-flow fan in FIG. **1**.

FIG. **15** is a graph showing the relation between the air flow rate of the cross-flow fan and power consumption of a driving motor in an example of the present invention.

FIG. **16** is a graph showing the relation between the air flow rate of the cross-flow fan and noise value in the example.

FIG. **17** is a graph showing pressure-flow rate characteristics of the cross-flow fan in the example.

DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention will be described with reference to the figures. In the following, the same or corresponding members in the figures are denoted with the same reference numerals.

First Embodiment

FIG. **1** is a side view of a cross-flow fan in a first embodiment of the present invention. FIG. **2** is a cross-sectional perspective view of the cross-flow fan taken along a line II-II in FIG. **1**.

Referring to FIG. **1** and FIG. **2**, a cross-flow fan **10** in the present embodiment has a plurality of fan blades **21**. Cross-flow fan **10** has an approximately cylindrical appearance as a whole. A plurality of fan blades **21** are arranged on a side surface of the approximately cylindrical shape. Cross-flow fan **10** is integrally formed from resin. Cross-flow fan **10** rotates in the direction shown by an arrow **103** around an imaginary center axis **101** shown in the figures.

Cross-flow fan **10** is a fan using a plurality of rotating fan blades **21** to flow air in a direction orthogonal to center axis **101** serving as the rotation axis. As viewed from the axial direction of center axis **101**, cross-flow fan **10** takes in air from an outside space on one side with respect to center axis **101** to an inside space of the fan and blows the taken-in air to the outside space on the other side with respect to center axis **101**. Cross-flow fan **10** forms an air flow that flows in the direction crossing center axis **101** in a flat plane orthogonal to center axis **101**. Cross-flow fan **10** forms an outlet flow in the form of a flat plane parallel to center axis **101**.

Cross-flow fan **10** is used with the rotation speeds in the low Reynolds number region applied to a fan for home electric equipment, etc.

Cross-flow fan **10** is configured such that a plurality of impellers **12** aligned in the axial direction of center axis **101** are combined. In each impeller **12**, a plurality of fan blades **21** are provided to be circumferentially spaced apart from each other around center axis **101**.

Cross-flow fan **10** further has a peripheral frame **13** serving as a support. Peripheral frame **13** has a ring shape annularly extending around center axis **101**. Peripheral frame **13** has an end surface **13***a* and an end surface **13***b*. End surface **13***a* is formed to face one direction along the axial direction of center axis **101**. End surface **13***b* is arranged on the back side of end surface **13***a* and is formed to face the other direction along the axial direction of center axis **101**.

Peripheral frame **13** is provided to be interposed between impellers **12** adjacent to each other in the axial direction of center axis **101**.

With attention given to impeller **12**A and impeller **12**B in FIG. **1** arranged adjacent to each other, a plurality of fan blades **21** provided in impeller **12**A are provided to stand on end surface **13***a* and are formed to extend like a plate along the axial direction of center axis **101**. A plurality of fan blades **21** provided in impeller **12**B are provided to stand on end surface **13***b* and are formed to extend like a plate along the axial direction of center axis **101**.

A plurality of fan blades **21** have a shape equal to each other. In the present embodiment, a plurality of fan blades **21** are arranged at a random pitch in the circumferential direction around center axis **101**.

Fan blade **21** has an inner edge portion **26** and an outer edge portion **27**. Inner edge portion **26** is arranged on an end portion at a radially inner side of fan blade **21**. Outer edge portion **27** is arranged at an end portion at a radially outer side of fan blade **21**. Fan blade **21** is formed to be inclined in the circumferential direction around center axis **101** from inner edge portion **26** toward outer edge portion **27**. Fan blade **21** is formed to be inclined in the rotation direction of cross-flow fan **10** from inner edge portion **26** toward outer edge portion **27**.

Fan blade **21** has a blade surface **23** including a pressure surface **25** and a suction surface **24**. Pressure surface **25** is arranged on the rotational direction side of cross-flow fan **10**. Suction surface **24** is arranged on the back side of pressure surface **25**. During rotation of cross-flow fan **10**, as an air flow is produced on blade surface **23**, a pressure distribution is generated such that pressure is relatively large at pressure surface **25** and is relatively small at suction surface **24**. Fan blade **21** has a shape generally curved between inner edge portion **26** and outer edge portion **27** so as to be concave on the pressure surface **25** side and be convex on the suction surface **24** side.

FIG. **3** is a cross-sectional view of the fan blade provided in the cross-flow fan in FIG. **1**. FIG. **3** shows a blade cross-sectional shape of fan blade **21** when it is cut along a plane orthogonal to center axis **101** serving as the rotation axis of cross-flow fan **10**.

Referring to FIG. **1** to FIG. **3**, fan blade **21** is formed to have the same blade cross-sectional shape when it is cut at any place in the axial direction of center axis **101**. Fan blade **21** is formed to have a thin blade cross-sectional shape. Fan blade **21** is formed to have a generally constant thickness (the length between pressure surface **25** and suction surface **24**) between inner edge portion **26** and outer edge portion **27**.

Fan blade **21** has such a blade cross-sectional shape that concave portions **57** are formed at pressure surface **25** of blade surface **23** and a concave portion **56** is formed at suction surface **24** of blade surface **23**. A plurality of concave portions **56**, **57** are formed at at least one of pressure surface **25** and suction surface **24**.

In the present embodiment, a plurality of concave portions **57** (concave portions **57***p*, **57***q*) are formed at pressure surface **25**. Convex portions **52** (**52***p*, **52***q*, **52***r*) are further formed at pressure surface **25**. Convex portion **52** is formed to protrude toward the rotation direction of cross-flow fan **10**. Concave portion **57** is formed by a valley portion between convex portions **52** arranged adjacent to each other. For example, concave portion **57***p* is formed by a valley portion between convex portion **52***p* and convex portion **52***q*. Concave portions **57** and convex portions **52** are formed to be alternately aligned in the direction in which inner edge portion **26** is connected with outer edge portion **27**. Concave portion **57** has an approximately U-shaped cross-sectional shape.

A plurality of convex portions **51** (convex portions **51***p*, **51***q*) are further formed at suction surface **24**. Convex portion **51** is formed to protrude toward the direction opposite to the rotation direction of cross-flow fan **10**. Concave portion **56** is formed by a valley portion between convex portions **51** arranged adjacent to each other. In the present embodiment, concave portion **56** is formed by a valley portion between convex portion **51***p* and convex portion **51***q*. Concave portion **56** and convex portions **51** are formed to be alternately aligned in the direction in which inner edge portion **26** is connected with outer edge portion **27**. Concave portion **56** has an approximately U-shaped cross-sectional shape.

Concave portion **57** and convex portion **51** are formed at front and back corresponding positions of pressure surface **25** and suction surface **24**, respectively. Convex portion **52** and concave portion **56** are formed at front and back corresponding positions of pressure surface **25** and suction surface **24**, respectively. In the present embodiment, concave portion **57** formed at pressure surface **25** forms convex portion **51** at suction surface **24**, and concave portion **56** formed at suction surface **24** forms convex portion **52** at pressure surface **25**. The concave portion and the convex portion formed at the front and the back correspondingly at pressure surface **25** and suction surface **24** have a cross-sectional shape equal to each other.

Concave portions **57**, **56** are each shaped like a groove extending along the axial direction of center axis **101**. The groove portion formed of each concave portion **57**, **56** is formed to continuously extend between one end and the other end of fan blade **21** in the axial direction of center axis **101**. The groove portion formed of each concave portion **57**, **56** is formed to linearly extend between one end and the other end of fan blade **21** in the axial direction of center axis **101**.

In the present embodiment, the number of concave portions **57** formed at pressure surface **25** is greater than the number of concave portion **56** formed at suction surface **24**.

FIG. **3** shows a center line **106** in the thickness direction (the direction in which pressure surface **25** is connected with suction surface **24**) of the blade cross-sectional shape of fan blade **21**. Fan blade **21** has flection portions **41** at which center line **106** of the blade cross-sectional shape of fan blade **21** is flexed at a plurality of points between inner edge portion **26** and outer edge portion **27**. Concave portions **56**, **57** are formed by flection portions **41**.

In the present embodiment, fan blade **21** has flection portions **41** at three points between inner edge portion **26** and outer edge portion **27**. Fan blade **21** has flection portions **41**A arranged in the proximity of inner edge portion **26** and outer edge portion **27**, respectively, and a flection portion **41**B arranged at a blade central potion between inner edge portion **26** and outer edge portion **27**. Flection portion **41**A forms concave portion **57** at pressure surface **25** and forms convex portion **51** at suction surface **24**. Flection portion **41**B forms convex portion **52** at pressure surface **25** and forms concave portion **56** at suction surface **24**.

With such a configuration, concave portions **57** are formed in the proximity of inner edge portion **26** and outer edge portion **27**, and concave portion **56** is formed at the blade central portion between inner edge portion **26** and outer edge portion **27**. Fan blade **21** has an approximately W-shaped blade cross-sectional shape.

Flection portions **41** are flexed such that the depth T of concave portions **56**, **57** is greater than the thickness t of fan blade **21** at at least one point. Flection portions **41** are formed such that the bending direction is alternately opposite in the direction in which inner edge portion **26** is connected with outer edge portion **27**. Flection portion **41** is formed to be bent in a rounded shape. Flection portion **41** may be formed to be bent to form a corner.

The structure of cross-flow fan **10** in the first embodiment of the present invention as described above is summarized as follows. Cross-flow fan **10** in the present embodiment includes a plurality of fan blades **21** as vane portions provided to be circumferentially spaced apart from each other. Fan blade **21** has inner edge portion **26** arranged on the radially inner side to/from which air flows in/out and outer edge portion **27** arranged on the radially outer side to/from which air flows in/out. Fan blade **21** has blade surface **23** extending between inner edge portion **26** and outer edge portion **27**. Blade surface **23** includes pressure surface **25** arranged on the rotation direction side of cross-flow fan **10** and suction surface **24** arranged on the back side of pressure surface **25**. When cut along the plane orthogonal to center axis **101** serving as the rotation axis of cross-flow fan **10**, fan blade **21** has such a blade cross-sectional shape that concave portions **57**, **56** are formed at pressure surface **25** and suction surface **24**. A plurality of concave portions **57** (**57***p*, **57***q*) are formed at pressure surface **25** as at least one of pressure surface **25** and suction surface **24**.

A structure of an air conditioner using cross-flow fan **10** in FIG. **1** will now be described.

FIG. **4** is a cross-sectional view of an air conditioner using the cross-flow fan shown in FIG. **1**. Referring to FIG. **4**, an air conditioner **110** is configured with an indoor unit **120** installed in a room and provided with an indoor heat exchanger **129** and a not-shown outdoor unit installed in the outside of the room and provided with an outdoor heat exchanger and a compressor. Indoor unit **120** and the outdoor unit are connected by piping for circulating refrigerant gas between indoor heat exchanger **129** and the outdoor heat exchanger.

Indoor unit **120** has a blower **115**. Blower **115** is configured to include cross-flow fan **10**, a not-shown driving motor for rotating cross-flow fan **10**, and a casing **122** for producing a prescribed airflow with rotation of cross-flow fan **10**.

Casing **122** has a cabinet **122**A and a front panel **122**B. Cabinet **122**A is supported on a wall surface in the room. Front panel **122**B is removably attached to cabinet **122**A. An outlet port **125** is formed in a gap between a lower end portion of front panel **122**B and a lower end portion of cabinet **122**A. Outlet port **125** is formed in an approximately rectangular shape extending in the width direction of indoor unit **120** and is provided to be directed forward and downward. On the top surface of front panel **122**B, a grid-like intake port **124** is formed.

At a position opposing front panel **122**B, an air filter **128** is provided for collecting and removing dust included in the air taken in from intake port **124**. A not-shown air filter cleaner is provided in a space formed between front panel **122**B and air filter **128**. The air filter cleaner automatically removes dust accumulated in air filter **128**.

In the inside of casing **122**, an air flow channel **126** is formed, through which air is circulated from intake port **124** toward outlet port **125**. Outlet portion **125** is provided with a vertical louver **132** that can change the blowing angle in the left and right directions and a plurality of horizontal louvers **131** that can change the blowing angle in the up and down directions to a forward-upward direction, a horizontal direction, a forward-downward direction, and an immediately downward direction.

Indoor heat exchanger **129** is arranged between cross-flow fan **10** and air filter **128** on a path of air flow channel **126**. Indoor heat exchanger **129** has not-shown serpentine refrigerant pipes arranged side by side in a plurality of layers in the up and down directions and in a plurality of columns in the front and back directions. Indoor heat exchanger **129** is connected to the compressor of the outdoor unit installed in the outdoor, and the compressor is driven to operate a refrigeration cycle. Through the operation of the refrigeration cycle, indoor heat exchanger **129** is cooled to a temperature lower than the ambient temperature during cooling operation, and indoor heat exchanger **129** is heated to a temperature higher than the ambient temperature during heating operation.

FIG. **5** is an enlarged cross-sectional view showing the proximity of the outlet port of the air conditioner in FIG. **4**. Referring to FIG. **4** and FIG. **5**, casing **122** has a front wall portion **151** and a rear wall portion **152**. Front wall portion **151** and rear wall portion **152** are arranged to face each other at a distance from each other.

On a path of air flow channel **126**, cross-flow fan **10** is arranged to be positioned between front wall portion **151** and rear wall portion **152**. A protrusion portion **153** is formed at front wall portion **151** to protrude toward the radially outer surface of cross-flow fan **10** so as to decrease the gap between cross-flow fan **10** and front wall portion **151**. A protrusion portion **154** is formed at rear wall portion **152** to protrude toward the radially outer surface of cross-flow fan **10** so as to decrease the gap between cross-flow fan **10** and rear wall portion **152**.

Casing **122** has an upper guide portion **156** and a lower guide portion **157**. Air flow channel **126** is defined by upper guide portion **156** and lower guide portion **157** on the downstream side of air flow from cross-flow fan **10**.

Upper guide portion **156** and lower guide portion **157** are continuous from front wall portion **151** and rear wall portion **152**, respectively, and extend toward outlet port **125**. Upper guide portion **156** and lower guide portion **157** are formed to curve the air blown by cross-flow fan **10** such that upper guide portion **156** is the inner circumferential side and lower guide portion **157** is the outer circumferential side, and to guide the air forward and downward. Upper guide portion **156** and lower guide portion **157** are formed such that the cross section of air flow channel **126** increases from cross-flow fan **10** toward outlet port **125**.

In the present embodiment, front wall portion **151** and upper guide portion **156** are integrally formed with front panel **122**B. Rear wall portion **152** and lower guide portion **157** are integrally formed with cabinet **122**A.

FIG. **6** is a cross-sectional view of an air flow produced in the proximity of the outlet port of the air conditioner in FIG. **4**. Referring to FIG. **5** and FIG. **6**, on the path on air flow channel **126**, an upstream outside space **146** is formed to be positioned upstream of air flow from cross-flow fan **10**, an inside space **147** is formed to be positioned in the inside of cross-flow fan **10** (the radially inner side of a plurality of fan blades **21** circumferentially arranged), and a downstream outside space **148** is formed to be positioned downstream of air flow from cross-flow fan **10**.

During rotation of cross-flow fan **10**, at an upstream region **141** of air flow channel **126** with respect to protrusion portions **153**, **154** as a boundary, an air flow **161** is formed to pass through on blade surface **23** of fan blade **21** from upstream outside space **146** toward inside space **147**. At a downstream region **142** of air flow channel **126** with respect to protrusion portions **153**, **154** as a boundary, air flow **161** is formed to pass through on blade surface **23** from inside space **147** toward downstream outside space **148**. Here, at a position adjacent to front wall portion **151**, a vortex **162** of air flow is formed.

FIG. **7** is a cross-sectional view representing a phenomenon that occurs on the blade surface of the fan blade in the upstream region shown in FIG. **5**. FIG. **8** is a diagram schematically representing the fan blade shown in FIG. **7**.

Referring to FIG. **7** and FIG. **8**, when an air flow directed from upstream outside space **146** toward inside space **147** is formed at upstream region **141**, an air flow is produced on blade surface **23** of fan blade **21** to flow in from outer edge portion **27**, pass through on blade surface **23**, and flow out from inner edge portion **26**. Here, a clockwise vortex **63** of air flow (secondary flow) is formed in concave portion **57** formed at pressure surface **25**, and a counterclockwise vortex **62** of air flow is generated at concave portion **56** formed at suction surface **24**. Accordingly, an air flow **61** (main flow) passing through on blade surface **23** flows along the outside of vortexes **63**, **62** produced at concave portions **57**, **56**.

FIG. **9** is a cross-sectional view representing a phenomenon that occurs on the blade surface of the fan blade in the downstream region shown in FIG. **5**. FIG. **10** is a diagram schematically representing the fan blade shown in FIG. **9**.

Referring to FIG. **9** and FIG. **10**, when an air flow directed from inside space **147** toward downstream outside space **148** is formed in downstream region **142**, an air flow is produced on blade surface **23** of fan blade **21** to flow in from inner edge portion **26**, pass through on blade surface **23**, and flow out from outer edge portion **27**. Here, a counterclockwise vortex **68** of air flow (secondary flow) is formed at concave portion **57** formed at pressure surface **25**, and a clockwise vortex **67** of air flow is generated at concave portion **56** formed at suction surface **24**. Accordingly, an air flow **66** (main flow) passing through on blade surface **23** flows along the outside of vortexes **68**, **67** produced at concave portions **57**, **56**.

In other words, in cross-flow fan **10**, when fan blade **21** moves from upstream region **141** to downstream region **142**, the direction of air flow on blade surface **23** is reversed, and the rotation directions of the vortexes produced at concave portions **57**, **56** are reversed accordingly.

In cross-flow fan **10** in the present embodiment, although having a thin blade cross-sectional shape, fan blade **21** exhibits a behavior like a thick blade as if the blade cross-sectional shape is increased in thickness by the depth of the concave portions **57**, **56** at which vortexes (secondary flows) are formed. As a result, the lift produced at fan blade **21** can be significantly increased. In addition, the flection structure of flection portions **41** can improve the strength of fan blade **21**. As a result, the reliability in strength of cross-flow fan **10** can be improved.

In cross-flow fan **10** in the present embodiment, concave portion **56** is formed at the blade central portion between inner edge portion **26** and outer edge portion **27**. Such a configuration further provides an effect of suppressing separation of airflow produced at the blade central portion. Accordingly, broadband noise generated in cross-flow fan **10** can be effectively suppressed.

In cross-flow fan **10** in the first embodiment of the present invention configured in this manner, the lift produced with rotation of fan blade **21** can be significantly increased in the low Reynolds number region applied to a fan for home electric equipment, etc. Accordingly, power consumption for driving cross-flow fan **10** can be reduced.

In cross-flow fan **10** in the present embodiment, while the strength of fan blade **21** is improved by flection portions **41**, the thickness of fan blade **21** can be reduced correspondingly. Accordingly, weight reduction and cost reduction of cross-flow fan **10** can be achieved. Because of the reasons above, cross-flow fan **10** having a blade cross-sectional shape with a high lift-drag ratio, with a small thickness and weight, and with a high strength can be obtained.

In air conditioner **110** in the first embodiment of the present invention, the use of cross-flow fan **10** having an excellent blowing capacity reduces power consumption of a driving motor for driving cross-flow fan **10**. Accordingly, it is possible to obtain air conditioner **110** that can contribute to energy savings.

Although an air conditioner has been described by way of example in this embodiment, the cross-flow fan in the present invention is also applicable to a fluid feeding device such as, for example, an air purifier, a humidifier, a cooling device, and a ventilating device.

Second Embodiment

In the present embodiment, a variety of modifications of cross-flow fan **10** in the first embodiment will be described.

FIG. **11** is a cross-sectional view of a first modification of the cross-flow fan in FIG. **1**. Referring to FIG. **11**, fan blade **21** has such a blade cross-sectional shape that a concave portion **77** is formed at pressure surface **25** and concave portions **76** are formed at suction surface **24**.

A plurality of convex portions **72** (**72***p*, **72***q*) are further formed at pressure surface **25**. Concave portion **77** is formed by a valley portion between the adjacent convex portions **72**. In this modification, a plurality of concave portions **76** (**76***p*, **76***q*) are formed at suction surface **24**. A plurality of convex portions **71** (**71***p*, **71***q*, **71***r*) are further formed at suction surface **24**. Concave portion **76** is formed by a valley portion between the adjacent convex portions **71**.

As compared with fan blade **21** in FIG. **3**, fan blade **21** has an approximately W-shaped blade cross-sectional shape in which the concave portion and the convex portion are reversed between pressure surface **25** and suction surface **24**. In this modification, the number of concave portions **76** formed at suction surface **24** is greater than the number of concave portion **77** formed at pressure surface **25**.

It is noted that the number of the concave portions formed at suction surface **24** may be equal to the number of the concave portions formed at pressure surface **25**.

FIG. **12** is a cross-sectional view of a second modification of the cross-flow fan in FIG. **1**. Referring to FIG. **12**, in this modification, a plurality of concave portions **77** (**77***p*, **77***q*, **77***r*) are formed at pressure surface **25**. A plurality of convex portions **72** (**72***p*, **72***q*, **72***r*, **72***s*) are further formed at pressure surface **25**. Concave portion **77** is formed by a valley portion between the adjacent convex portions **72**. A plurality of concave portions **76** (**76***p*, **76***q*) are formed at suction surface **24**. A plurality of convex portions **71** (**71***p*, **71***q*, **71***r*) are further formed at suction surface **24**. Concave portion **76** is formed by a valley portion between the adjacent convex portions **71**.

As shown in this modification, a plurality of concave portions may be formed both at pressure surface **25** and at suction surface **24**.

FIG. **13** is a cross-sectional view of a third modification of the cross-flow fan in FIG. **1**. Referring to FIG. **13**, in this modification, fan blade **21** has such a blade cross-sectional shape as a whole that the thickness is relatively small at positions adjacent to inner edge portion **26** and outer edge portion **27** and the thickness gradually increases as it is closer to the blade central portion between inner edge portion **26** and outer edge portion **27**.

Concave portion **77***p* and concave portion **77***q* are formed to be positioned in the proximity of inner edge portion **26** and outer edge portion **27**, respectively, at pressure surface **25**. Concave portion **76** is formed to be positioned at the blade central portion between inner edge portion **26** and outer edge portion **27**, at suction surface **24**. Concave portions **77** and concave portion **76** are formed to be recessed from the surface of blade surface **23** extending to be curved between inner edge portion **26** and outer edge portion **27**. Concave portions **77** and concave portion **76** are formed such that a thickness t**1** of fan blade **21** at a position having concave portion **77***p*, a thickness t**2** of fan blade **21** at a position having concave portion **76**, and a thickness t**3** of fan blade **21** at a position having concave portion **77***q* are equal.

As shown in this modification by way of example, fan blade **21** is not limited to a structure having a thin cross-sectional shape as a whole but may have any other cross-sectional shape. Fan blade **21** is not limited to a structure in which concave portions **57** and concave portion **56** are formed by flection portions **41** as shown in FIG. **3** but may be structured such that concave portion **76** and concave portions **77** are formed by partially recessing blade surface **23** extending in a flat shape or curved shape as in this modification.

The cross-flow fan in the third embodiment of the present invention configured in this manner can achieve the effect described in the first embodiment, similarly.

Third Embodiment

In the present embodiment, a molding die for use in production of cross-flow fan **10** in FIG. **1** will be described.

FIG. **14** is a cross-sectional view of a molding die for use in production of the cross-flow fan in FIG. **1**. Referring to FIG. **14**, a molding die **210** has a stationary die **214** and a movable die **212**. Stationary die **214** and movable die **212** define a cavity **216** which has approximately the same shape as cross-flow fan **10** and into which flowable resin is injected.

Molding die **210** may be provided with a not-shown heater for increasing the flowability of resin injected into cavity **216**. The installation of such a heater is particularly effective, for example, when synthetic resin with an increased strength, such as glass-fiber-filled AS resin, is used.

With molding die **210** configured in this manner, a cross-flow fan having a blade cross-sectional shape with a high drag-lift ratio, with a small thickness and weight, and with a high strength can be manufactured by resin molding.

Fourth Embodiment

In the present embodiment, each of cross-flow fan **10** shown in FIG. **1** and a cross-flow fan for comparison having a fan blade without a concave portion and a convex portion formed on blade surface **23** is mounted in air conditioner **110** shown in FIG. **4**. Each example carried out using that air conditioner **110** will be described.

In the example described below, cross-flow fan **10** and the cross-flow fan for comparison each having a diameter of 100 mm and a length of 600 mm were used, where the shape including the size and arrangement of fan blade **21** was the same excluding the presence/absence of the concave portion and the convex portion.

FIG. **15** is a graph showing the relation between the air flow rate of the cross-flow fan and the power consumption of a driving motor in the example. Referring to FIG. **15**, in the example, the power consumption of the driving motor was measured at various air flow rates, in each of the case using cross-flow fan **10** and the case using the cross-flow fan for comparison. As a result of measurement, it was confirmed that as compared with the cross-flow fan for comparison, cross-flow fan **10** reduced power consumption of the driving motor at the same flow rate.

FIG. **16** is a graph showing the relation between the air flow rate of the cross-flow fan and noise value in the example. Referring to FIG. **16**, in the example, the noise value was measured at various air flow rates, in each of the case using cross-flow fan **10** and the case using the cross-flow fan for comparison. As a result of the measurement, it was confirmed that as compared with the cross-flow fan for comparison, cross-flow fan **10** reduced the noise value at the same flow rate.

FIG. **17** is a graph showing pressure-flow rate characteristics of the cross-flow fan in the example. Referring to FIG. **17**, the figure shows the pressure-flow rate characteristics (P: static pressure-Q: air flow rate) of cross-flow fan **10** and the cross-flow fan for comparison at a constant rotation speed. Referring to FIG. **17**, cross-flow fan **10** improved in the P-Q characteristics specifically in a small air flow rate region, as compared with the cross-flow fan for comparison.

The structures of the cross-flow fan as described in the foregoing first and second embodiments may be combined as appropriate to form a new cross-flow fan. The molding die and the fluid feeder described in the first and third embodiments are applicable to a variety of cross-flow fans described in the first and second embodiments and to a cross-flow fan formed of a combination thereof.

The embodiment disclosed here should be understood as being illustrative rather than being limitative in all respects. The scope of the present invention is shown not in the foregoing description but in the claims, and it is intended that all modifications that come within the meaning and range of equivalence to the claims are embraced here.

INDUSTRIAL APPLICABILITY

The present invention is mainly applied to home electric equipment having an air blowing function, such as an air purifier and an air conditioner.

REFERENCE SIGNS LIST

10 cross-flow fan, **12**, **12**A, **12**B, impeller, **13** peripheral frame, **13***a*, **13***b* end surface, **21** fan blade, **23** blade surface, **24** suction surface, **25** pressure surface, **26** inner edge portion, **27** outer edge portion, **41**, **41**A, **41**B flection portions, **51**, **52**, **71**, **72** convex portion, **56**, **57**, **76**, **77** concave portion, **61**, **66**, **161** air flow, **62**, **63** **67**, **68**, **162** vortex, **101** center axis, **106** center line, **110** air conditioner, **115** blower, **120** indoor unit, **122** casing, **122**A cabinet, **122**B front panel, **124** intake port, **125** outlet port, **126** air flow channel, **128** air filter, **129** indoor heat exchanger, **131** horizontal louver, **132** vertical louver, **141** upstream region, **142** downstream region, **146** upstream outside space, **147** inside space, **148** downstream outside space, **151** front wall portion, **152** rear wall portion, **153**, **154** protrusion portion, **156** upper guide, **157** lower guide, **210** molding die, **212** movable die, **214** stationary die, **216** cavity

The invention claimed is:

1. A cross-flow fan comprising a plurality of vane portions provided to be circumferentially spaced apart from each other, each having an inner edge portion arranged on a radially inner side to/from which air flows in/out and an outer edge portion arranged on a radially outer side to/from which air flows in/out, wherein

said vane portion has a blade surface extending between said inner edge portion and said outer edge portion and including a pressure surface arranged on a rotation direction side of the cross-flow fan and a suction surface arranged on a back side of said pressure surface,

said vane portion has such a blade cross-sectional shape that a concave portion is formed at said pressure surface and said suction surface when said vane portion is cut along a plane orthogonal to a rotation axis of the cross-flow fan,

a plurality of said concave portions are formed at at least one of said pressure surface and said suction surface, and

the number of said concave portions formed at said pressure surface is greater than the number of said concave portions formed at said suction surface.

2. The cross-flow fan according to claim **1**, wherein

said vane portion has a flection portion formed by flexing a center line of said blade cross-sectional shape extending between said inner edge portion and said outer edge portion, at a plurality of points, and

said concave portion is formed by said flection portion.

3. The cross-flow fan according to claim **2**, wherein said flection portion is flexed such that a depth of said concave portion is larger than a thickness of said vane portion at at least one point.

4. The cross-flow fan according to claim **1**, wherein said concave portion is formed in the proximity of said inner edge portion and said outer edge portion.

5. The cross-flow fan according to claim **1**, wherein said concave portion is formed at a blade central portion between said inner edge portion and said outer edge portion.

6. The cross-flow fan according to claim **1**, wherein said concave portion is formed at said pressure surface and said suction surface to repeatedly appear in a direction in which said inner edge portion is connected with said outer edge portion.

7. The cross-flow fan according to claim **1**, wherein said concave portion formed at said pressure surface forms a convex portion at said suction surface, and said concave portion formed at said suction surface forms a convex portion at said pressure surface.

8. The cross-flow fan according to claim **1**, wherein

in said blade cross-sectional shape, said concave portion is formed between convex portions appearing at said blade surface, and

said concave portion and said convex portions are formed to be alternately aligned in a direction in which said inner edge portion is connected with said outer edge portion.

9. The cross-flow fan according to claim **1**, wherein said vane portion has said blade cross-sectional shape having a generally constant thickness between said inner edge portion and said outer edge portion.

10. The cross-flow fan according to claim **1**, wherein said blade cross-sectional shape is approximately W-shaped.

11. The cross-flow fan according to claim **1**, wherein the cross-flow fan is made of resin.

12. A fluid feeder comprising a blower configured to include the cross-flow fan of claim **1** and a driving motor coupled to said cross-flow fan to rotate a plurality of said vane portions.

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